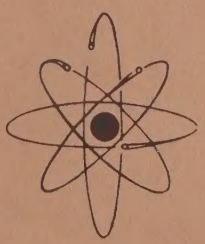
STORES NUMBER 902021

Instruction Manual

RATEMETER SET

MODEL 916434



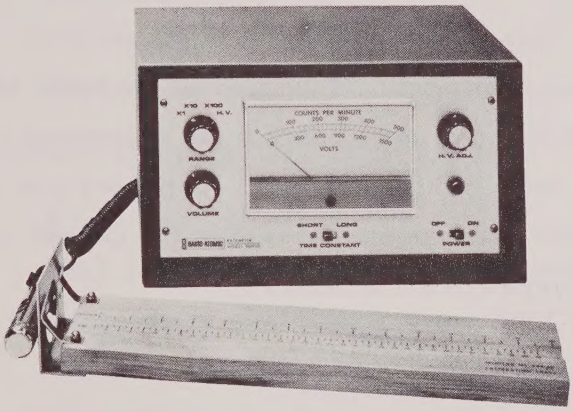
headquarters for ALL nuclear accessories!

BAIRD-ATOMIC

ATOMIC AND LABORATORY INSTRUMENT DIVISION

125 MIDDLESEX TURNPIKE, BEDFORD, MASSACHUSETTS 01730

Instruction Manual



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WARNING

The instrument described in this manual operates at high voltages. Do not attempt to operate the ratemeter until you have read all material in Section II. Improper use may result not only in permanent damage to the Geiger counter, but also in severe electrical shock.

CONTENTS

		Page
	SAFETY PRECAUTIONS WHILE HANDLING RADIOISOTOPES	iv
SECTION I	BACKGROUND AND THEORY	1
	Nature of Radioactivity	1
	Measurement of Radioactivity	2
	The Geiger Counter	3
	Efficiency of Detecting Instruments	4
	Experiment Board	6
SECTION II	OPERATION OF THE INSTRUMENT	7
	Front Panel Controls	7
	Rear Panel Controls and Connectors	9
	Preparation of the Instrument for Counting	9
	Hints for Observing the Count Rate	10
	Determination of Background	11
APPENDIX	DETECTOR PLATEAU CURVE	13

ILLUSTRATIONS

1	Cutaway of Side-Window Geiger-Mueller Tube	3
2	Experiment Board	6
3	Ratemeter, Geiger-Mueller Tube and Experiment Board	7
4	Ratemeter, Rear Panel	9

SAFETY PRECAUTIONS WHILE HANDLING RADIOISOTOPES

Many laboratory substances (acids, alkalies, poisons, etc.) require careful handling; radioactive materials are no exception. Proper care and common sense should always be practiced in the laboratory. Under care, the following rules apply.

1. Wear surgeon's rubber gloves when working with liquid radioactive materials.

2. Handle liquid radioactive materials over a tray lined with absorbent paper to localize spills.

3. Mark all vessels containing radioactive materials (liquid or solid) with the approved radiation symbol.

4. Before removing the rubber gloves, wash them with generous quantities of soap and water.

5. When manipulating radioactive sources, liquid or solid, don't allow the hands to come in direct contact with them. Use a pair of forceps. Wash your hands after every experiment.

SECTION I -- BACKGROUND AND THEORY

NATURE OF RADIOACTIVITY

One of the first men to observe the phenomenon of radioactivity was Henri Becquerel, who discovered in the 19th Century that unexposed photographic film became fogged when placed near uranium salts. Since light rays had not been allowed to strike the film, Becquerel concluded that the uranium must have been producing rays which, like light rays, were able to be recorded photographically.

Later, it was discovered that these invisible rays were being caused by changes taking place within the nucleus of the uranium atom -- changes which were leading to a more stable arrangement of that nucleus. It was generally found that elements of an atomic number greater than 82 were naturally radioactive.

Study of radioactivity revealed that it is actually composed of more than one ingredient.

1. Alpha Particles: positively charged and identical to the nuclei of helium atoms, differing only in origin. Because of their relatively low velocity (0.1 the speed of light) and great charge, they possess great ionizing power. All alpha particles emitted from the same nucleus are identical in energy and hence are called mono-energetic. Alpha particles may be stopped by a thin sheet of paper.

2. Beta Particles: negatively charged and identical to an electron, differing only in origin. They travel at velocities up to 0.9 the speed of light. Unlike the case of alpha particles, the energy of emitted beta particles varies widely, leading also to wide variation in speed. Beta particles are more penetrating than alpha particles but may be stopped by thick plastic constructions.

3. Gamma Rays: not particles, but rays closely resembling x-rays although usually of shorter wavelengths. Since gamma rays have no charge, they do not react with matter in the same manner as do alpha and beta particles. They travel at the speed of light and have great penetrating power; a foot of lead is necessary for absorption.

Further investigation into the nature of radioactivity yielded evidence that, even among the atoms of a single element, the nuclei were not necessarily alike. The nuclei may differ in the number of neutrons they possess, while the number of protons remain the same. A change in the number of neutrons within

a nucleus consequently results in a change in the atomic weight (protons + neutrons). When an atom having a different atomic weight from the usual for that particular element was found, that atom was called an isotope.

Isotopes which emit radiation are called radioisotopes. Many of these isotopes have been identified and recorded. Even the naturally radioactive elements (those of an atomic number greater than 82) were found to possess several different isotopes. Some isotopes have always been present on earth, while others are constantly being created by man through changes he brings about in the nuclei of atoms.

MEASUREMENT OF RADIOACTIVITY

Radioactivity may be defined as the rate of disintegration of the nuclei of certain atoms within a sample. If a sample is said to have a great degree of radioactivity, the nuclei of the atoms within are disintegrating at a rapid rate.

The unit of measure for radioactivity which is most commonly used in nuclear science is the curie (Ci). A curie is defined as the unit quantity of any radioactive substance in which 3.7×10^{10}, or 37 billion disintegrations occur per second (dps). Thus:

one curie (1 Ci) $= 3.7 \times 10^{10}$ dps

one millicurie (1 mCi) $= 3.7 \times 10^{7}$ dps

one microcurie (1 μCi) $= 3.7 \times 10^{4}$ dps

To attempt to count the disintegrations taking place within a certain period of time (determining the absolute activity of a sample) is too difficult. What is more practical for the experimenter is the determination of the relative activity. Relative activity of a sample, a measurement useful in 90 percent of the experiments, may be determined through the use of any of several detecting instruments.

Radioactivity may be expressed by the detecting instrument in a variety of ways: counts per minute, as in the case of the Geiger counter; clicks per minute (heard on headphones or a speaker), as in radiation counters used by uranium prospectors; the darkness of an image on photographic film; or the rate of drift of a quartz fiber, as in the electroscope.

The most common methods for detection of radiation are those which utilize the electrical effects of the ionization caused by radioactive emissions. Alpha and beta particles directly ionize, while gamma rays bring about ionization indirectly.

THE GEIGER COUNTER

Commonly thought of as one instrument, the Geiger counter is actually a combination of two separate devices: a Geiger-Mueller (GM) tube for the detection of radioactivity and an instrument such as a ratemeter or a scaler for the conversion of electrical signals (from the GM tube) into useful data. The GM tube consists of a cylinder (made of thin glass or metal) containing two electrodes and a special gas mixture. The positive electrode (anode) is a thin wire, mounted in the center of the tube, concentric with the tube wall (figure 1). In a metal-walled tube, the cylinder itself serves as the negative electrode (cathode); in a glass-walled tube, a thin, metallic coating on the inside of the cylinder wall serves as the cathode. The gas inside the cylinder is a special mixture which is easily ionized and yet recovers readily from the ionization.

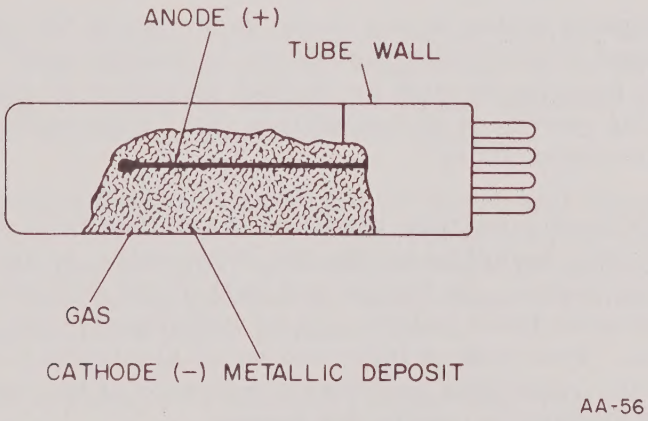


Figure 1. Cutaway of Side-Window Geiger-Mueller Tube

The GM tube is charged with an electrical potential of high voltage. The electronic measuring instrument (count-ratemeter, scaler, etc.) provides the electrical potential required to charge the GM tube. Radiation passing into the GM tube ionizes the gas either directly, as with alpha and beta particles, or indirectly, as with gamma rays. Ionization results in the presence within the tube of positive gas ions, negative gas ions, and free electrons. The negative gas ions and the free electrons are strongly attracted to the powerful positive charge of the anode wire, and the positive ions are strongly attracted to the powerful negative charge of the cathode. Electrons are very capable of ionizing additional gas molecules. In their rapid flight to the anode, they collide with gas molecules releasing more positive and negative ions and electrons. These new electrons ionize additional gas molecules in ever-increasing numbers and

build into a snowballing or avalanche effect. Hence, from a single impact of one radioactive particle, an avalanche of electrons strikes the anode. The anode consequently experiences a drop in electrical potential, which results in an electrical pulse being received by the associated measuring instrument (ratemeter, scaler, etc.). All of this normally takes place within a fraction of a second.

Because of the GM tube's avalanching effect, a single impact from a radioactive particle would result in a continual discharge of electrical current (making it impossible to count individual impacts) if this effect were not counteracted in some way. The avalanche must be immediately stopped and the GM tube must be restored to its original (sensitive) state. To accomplish this, another gas in the mixture absorbs part of the energy of the electrons and the ions remaining after the initial ionizing event. The discharge of the GM tube is consequently limited to a pulse of very short duration (approximately 150 microseconds) and the tube is immediately restored to count further impacts.

This absorptive action of one of the gases in the GM tube is called quenching. One of two types of quenching techniques is usually used: organic quenching, using organic compounds such as alcohol or butane as the agent; or halogen quenching,using members of the halogen family (bromine, chlorine, iodine, etc.) and their compounds.

The avalanche of electrons resulting in an electrical discharge from the GM tube, immediately quenched by the gas in the tube, is received by the ratemeter as an electrical pulse. As the second part of the GM tube-ratemeter team, the ratemeter converts these pulses into an indication of the rate at which the pulses are occurring. This rate is indicated on an electrical meter, hence the term, ratemeter. The ratemeter provides a measure of the relative disintegration rate and is expressed in counts per minute.

EFFICIENCY OF DETECTING INSTRUMENTS

The efficiency of a detecting instrument is an indication of the number of ionizing events counted, as compared with the number of particles actually emitted. If 4×10^{10} particles are being emitted each second, and the instrument detects 2×10^{10} particles, its efficiency would be 50 percent.

The efficiency of a detecting system depends upon many factors. Among these, the most important factors are

1. the type of radiation to be detected,

2. the type of instrument used as the detector, and

3. the geometry of the detecting system.

The characteristics (energy, speed, penetrability, etc.) of each type of radiation governs the value of a particular type of detecting system. If a detector is not sensitive enough to detect weak betas, or if it cannot be penetrated by alpha particles, then its value in the detection of alpha and beta particles is questionable. Unless the wall of the GM tube is very thin, the easily stopped alpha particle will not pass through it but will be deflected. Most beta particles are efficiently detected by the GM tube (the exception involves those betas of extremely low energy, such as those emitted by carbon 14, which are detected only at extremely low percent efficiency). Because they are not charged particles, gamma rays pass completely through the tube for the most part, unless they are of extremely low energy. Consequently, the detection efficiency of a GM tube is somewhat lower for gamma rays than for alpha and beta particles. Many gamma rays in passing completely through the tube, fail to create ionization in the gas. Placing a shield in front of the tube results in absorption of alpha and beta particles, so that only the gamma rays enter the tube and are subsequently counted.

The GM tube is usually encased in a metal cylinder (probe), which protects the delicate walls. The cylinder has several open areas which permit beta particles to pass through the tube for detection. When detecting high-energy gamma rays, the metal shield is closed over the openings.

Just as a GM tube shield may be used to permit entry and measurement of gamma rays alone, many different selective absorbers may be placed between a radioactive source and the GM tube, in order to block all radiation below a certain, desired level from being measured. Absorbers are made of a multitude of materials, ranging from paper to lead.

The geometry of the system is particularly important in this discussion. Radiation is emitted from a source in all directions. It would be very difficult, however, to mount a sample in mid-air and place it within a detecting instrument. The sample needs a mounting device convenient for both safe handling and reproducibility of results. Small, shallow dishes, called planchets, are used for this purpose.

When planchets or other suitable holders are used, it is possible to place the sample close to the GM tube. Even so, the GM tube does not detect all of the radiation emitted from the sample (figure 2). A Geiger counter may achieve 10-percent efficiency in measuring beta particles emitted from a sample close to the tube, while its efficiency in measuring gamma rays rarely exceeds 2 percent.

Shifting the position of the sample will cause changes in detected radioactivity. It is most important, then, in obtaining measurements of radioactivity to keep all of the factors mentioned above constant, except for changes in the sample used.

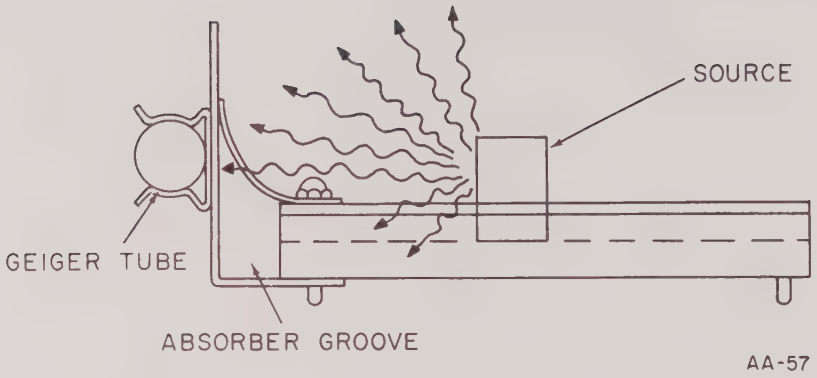


Figure 2. Experiment Board

EXPERIMENT BOARD

The Experiment Board (figure 2) serves as a mount for the GM tube, absorbers and the sample. In addition, the board provides a simple method of positioning the source at varying distances from the tube.

The clamp which holds the GM tube probe is mounted on a bracket which is fastened to one end of the Experiment Board. Absorbers are slipped into place on the opposite face of the bracket. They are held in place against this bracket by means of spring clips mounted on the Experiment Board.

The board has a V-shaped groove in the center, running through its length. The groove holds the cylindrically shaped source erect, facing the GM tube, allowing for precise adjustment of source-to-detector distance. Distance is expressed on the Experiment Board in both inches and centimeters.

SECTION II -- OPERATION OF THE INSTRUMENT

CAUTION

Read the following material carefully before you plug in this instrument. Familiarize yourself with the controls and the proper method of operation. Improper operation of the ratemeter may result in permanent damage to the Geiger-Mueller (GM) tube.

FRONT PANEL CONTROLS

Figure 3 shows the front panel controls.

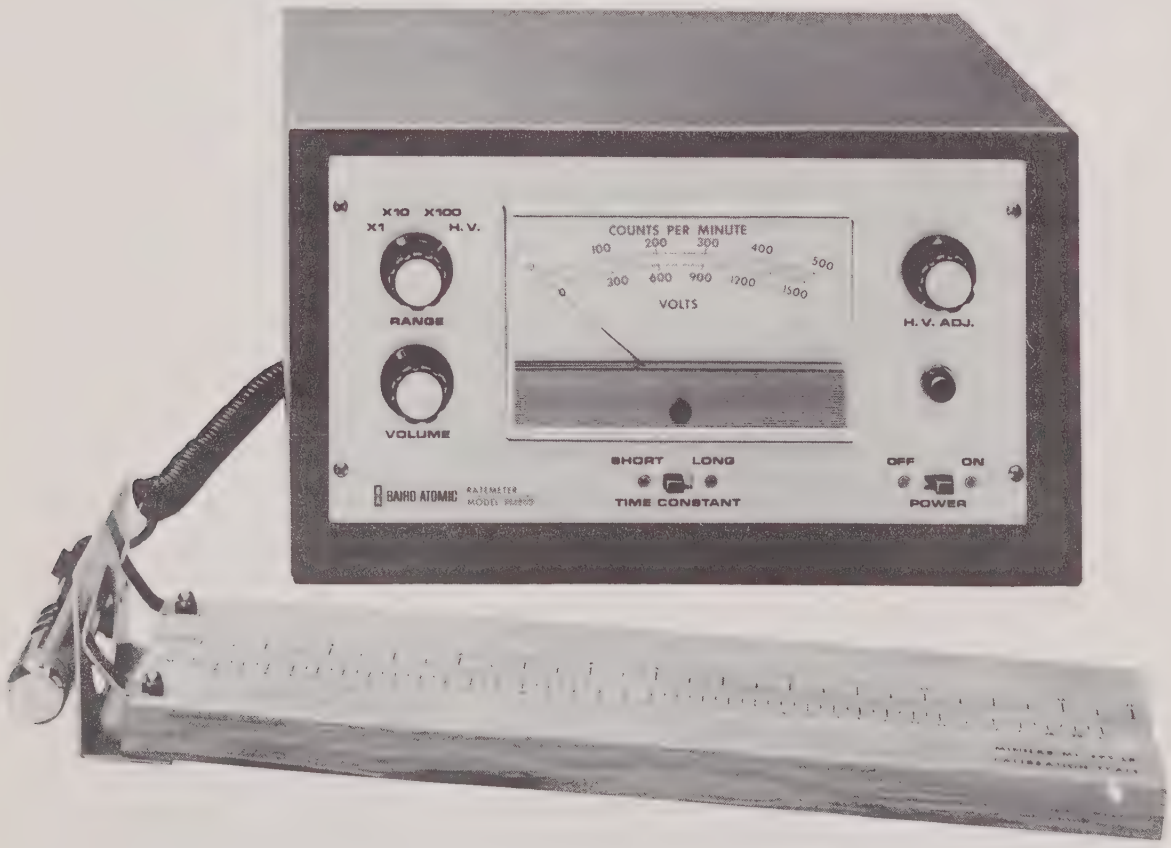


Figure 3. Ratemeter, Geiger-Mueller Tube and Experiment Board

1. Meter: dual-purpose type; the top scale (COUNTS PER MINUTE) indicates the count rate when the selector switch is set at any one of the three ranges; the bottom scale (VOLTS) indicates the voltage applied to the GM tube when the selector switch is set at H. V.; the panel meter does not indicate on both scales simultaneously: the selector switch position determines which scale is to be read.

   On the H. V. scale, the meter reads from 0 to 1500 volts, in increments of 20 volts.

   The upper scale of the meter reads from 0 to 500 and may indicate one of three ranges, depending on the position of the selector switch. If this switch is set at X1 (multiplied by 1), then the upper scale readings are as shown, 0 to 500 counts per minute (CPM). If the selector switch is set at X10, all readings are multiplied by 10 (500 on the upper scale would then represent 5000 CPM). If the selector switch is set on X100, all readings are multiplied by 100 (500 on the upper scale would then mean 50,000; 400 would mean 40,000, etc.). Interpreting the scale range improperly is one of the main reasons for incorrect readings.

2. RANGE Switch: This 4-position switch is the most frequently used of all controls on the front panel: X1, X10 and X100 set the scale ranges to be used in reading the panel meter.

   H. V. position allows the operator to monitor the high voltage applied to the GM tube.

3. H. V. ADJ.: controls the high voltage applied to the GM tube. This control is never changed unless the operator is monitoring the high voltage scale (RANGE switch set on H. V.) on the meter. Excessive high voltage may result in damage to the GM tube.

4. POWER: (OFF, ON) turns the ratemeter and GM tube power supply on and off.

5. TIME CONSTANT Switch (two positions): SHORT (1 second) and LONG (10 seconds). It determines how fast the ratemeter will react to changes in the count rate (how fast the meter needle will change its reading). It should be set on SHORT when rapid changes in the count rate are being observed. For ease and accuracy of readings, especially when low counting rates are being observed, the LONG position should be used.

6. VOLUME: adjusts the loudspeaker, which provides an audible indication of the count rate by making a click for every count. The loudspeaker is especially useful when finding the background count.

REAR PANEL CONTROLS AND CONNECTORS

Figure 4 shows the controls of connectors on the rear panel.

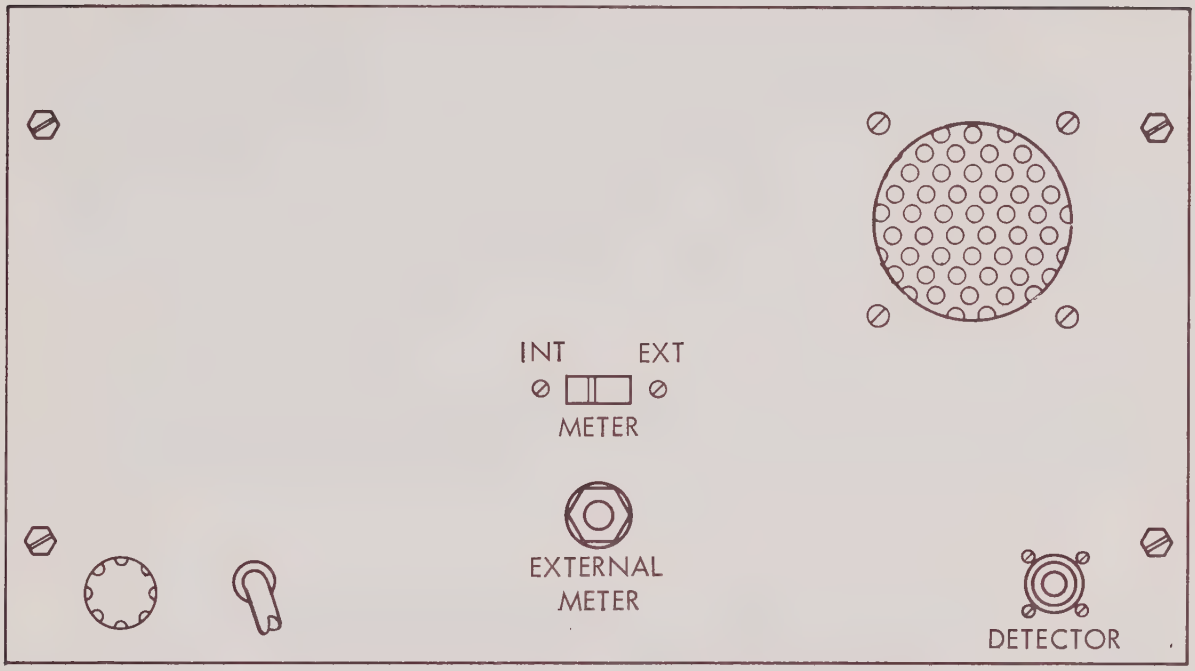


Figure 4. Ratemeter, Rear Panel

1. Power Cord: plugs into any 115-volt 60-cycle a-c outlet.

2. DETECTOR: accepts the cable from a GM tube.

3. EXTERNAL METER: accepts cable from an external measuring meter, such as a classroom-type projection meter.

4. METER Switch: when set on EXT, allows use of external meter for monitoring the count rate, while disabling the internal meter; when set on INT, allows normal meter function. This switch is always on the INT position unless an external meter is used.

PREPARATION OF THE INSTRUMENT FOR COUNTING

1. Before the instrument is plugged in, make certain to have the POWER switch in the OFF position and to rotate the H. V. ADJ. knob fully counterclockwise.

2. Connect the GM tube cable to the DETECTOR connection on the rear panel of the ratemeter. The GM tube should be clamped to the Experiment Board (figure 3). Place a sample on the Experiment Board.

3. Plug in the power cord.

4. Turn the RANGE switch to H. V. and the POWER switch to ON. Allow five minutes for the ratemeter to warm up.

5. Rotate the H. V. ADJ. knob slowly reading the voltage on the front panel meter, until you have arrived at the proper operating voltage for the particular GM tube being used. This figure will be supplied by the instructor. If the instructor desires you to determine the proper voltage by yourself, turn to the appendix of this manual for instructions on the detector plateau curve experiment. Do not attempt to set the high voltage unless you have secured the proper figure from either the instructor or the appendix.

6. Rotate the volume control to about half of its maximum setting. If a louder click is needed, increase the setting to the level desired.

7. When step 6 is completed, turn the RANGE switch to the X100 position.

NOTE

To prevent damage to the meter, always start readings at the highest multiplication factor (X100) on the RANGE switch.

If the reading is below the fifth subdivision on the count rate scale, switch to the X10 range. If the reading remains below the fifth subdivision on the scale, switch to the X1 range. If the meter completely fails to register a count, check METER switch on rear panel to ensure that it is on INT position.

HINTS FOR OBSERVING THE COUNT RATE

The count rate as presented on the meter is directly proportional to the radioactivity of the sample being measured. Consequently, the activity of a sample may be expressed as a count rate.

Because the radioactive atoms in the samples are decaying at a random, rather than an absolutely constant rate, the panel meter will not remain steady when you are taking a reading. The meter needle fluctuates slightly above and below the average count rate. The use of the TIME CONSTANT switch placed on LONG will decrease the fluctuation to a degree, depending on the type of sample used. Samples of a high count rate may produce little or no fluctuation of the meter, whereas samples of low count rate will show wide fluctuations. When first placing a sample on the Experiment Board, always wait one minute before taking a reading. This will enable the instrument's time constant device to reach a stage of equilibrium, thus steadying the meter fluctuations.

If, despite all precautions, the meter fluctuates, remember that accurate readings may still be made. Try to obtain an average reading. The needle will move back and forth, but it will usually remain around an average value longer than it will remain among the higher and lower values observed. This average value is the reading which should be recorded as the count rate.

DETERMINATION OF BACKGROUND

The GM tube is constantly being struck by radiation other than that which is coming from the sample (cosmic rays, radium salts in the soil, luminous watch dials, etc.). This radiation adds to the total radiation detected by the GM tube.

To determine the background:

1. Remove all radioactive sources from the area.

2. Set the ratemeter at the proper operating voltage for the GM tube being used.

3. Turn up the VOLUME control knob.

4. Listening carefully to the loudspeaker, count the number of clicks which occur in a 1-minute time period and record the total. Because of the extremely low count rate, your panel meter will not be able to average the background count and indicate it on the counts per minute scale.

5. Subtract the background from all future readings to obtain the corrected activity, or the corrected count rate.

NOTE

"Minilab" includes the following radioactive sources:

917352	Model R-351	Radium gamma source, 15 micrograms
917353	Model SB-353	Strontium 90 beta source, 0.5 microcurie

APPENDIX

THE DETECTOR PLATEAU CURVE

One of the characteristics exhibited by Geiger-Mueller (GM) tubes is the dependence of the count rate on the value of the high voltage applied to the detector (GM tube). However, if you were to plot a curve using high voltage versus count rate, you would find that there is a portion of the curve, a plateau, at which the count rate is relatively independent of the high voltage setting. This plateau represents a range of operating voltages which would yield the most practical results.

To set the ratemeter for the proper operating voltage for your experiments, you must plot the detector plateau curve, using a radioactive sample at a fixed distance from the detector. Gradually increase the high voltage from zero until you have the first indications of a count rate on the meter (starting potential). From this point, as you increase the voltage, the count rate will increase until it reaches the threshold of the plateau. The proper operating voltage along this curve for the operation of your ratemeter-GM tube system is located at a point 50 volts above the threshold (lower knee) of the plateau.

OBTAINING THE PLATEAU CURVE

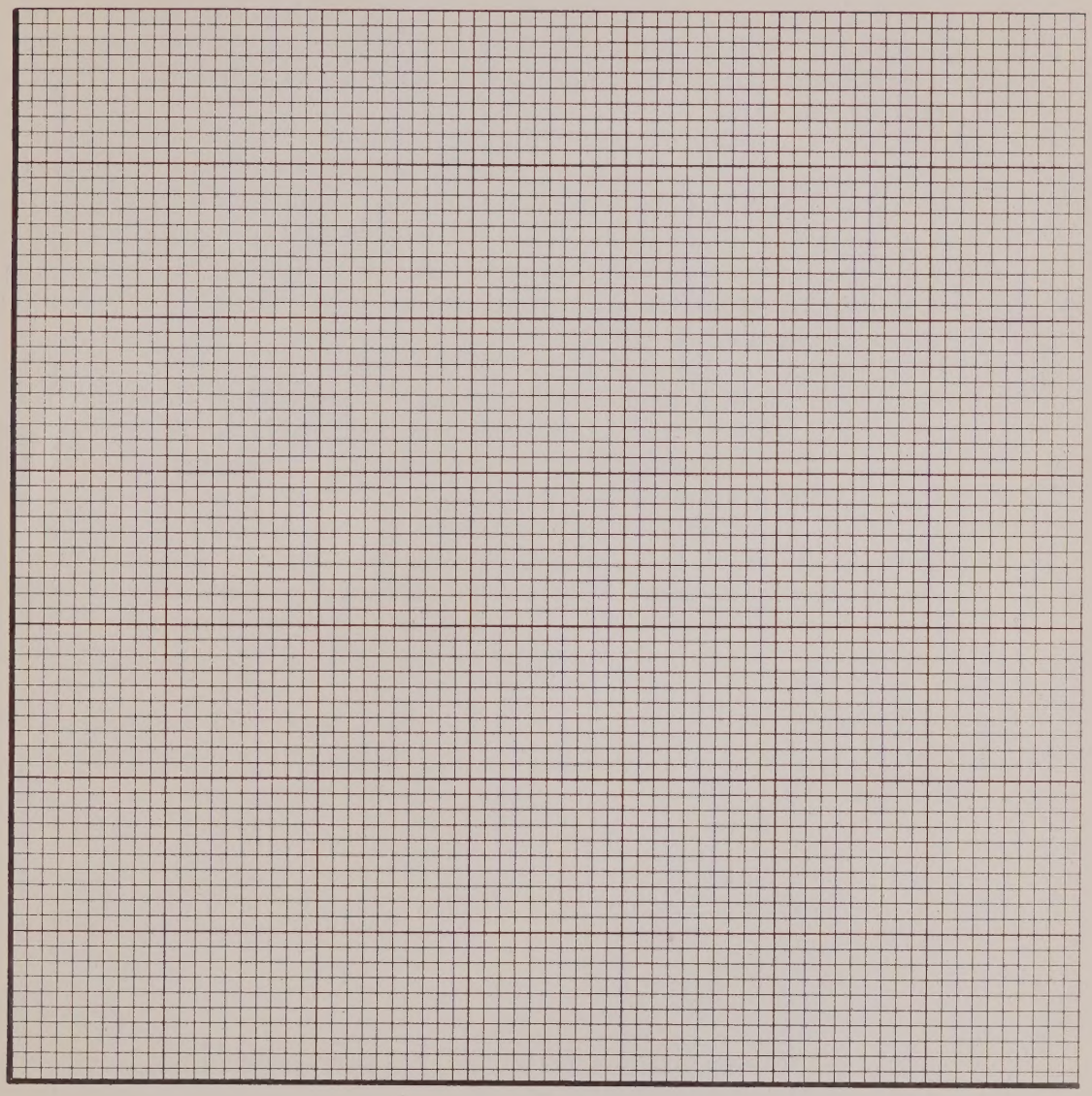
1. Turn POWER switch to the OFF position.
2. Connect the GM tube to the DETECTOR receptacle on the rear panel of the ratemeter.
3. Always set the H. V. ADJ. control fully counterclockwise to ensure against damage to the detector.
4. Turn POWER switch to ON.
5. Place a radioactive source in position on the Experiment Board.
6. Set the RANGE switch to X100.*
7. Set the TIME CONSTANT switch to SHORT.

---

*If the meter reading for count rate remains very low on the scale for the entire procedure, consequently making precise figures difficult, the RANGE switch may be set at X10 or even X1, if you remember to multiply by that factor when recording the count rate on the data table. Remember also that, if you choose a meter range which allows the needle to go beyond its maximum indication, you will be doing permanent damage to the sensitive meter movement.

DATA TABLE

GM Tube Voltage (volts)	Counts per Minute



Activity (counts per minute)

Geiger-Mueller Tube Voltages (volts)

VOLTAGE VERSUS COUNT RATE

8. Find the starting potential by slowly increasing the H. V. ADJ. control (clockwise) until a count rate indication shows on the meter. Turn the RANGE switch to H. V. and note the voltage scale reading. This is your starting potential.

9. Using the H. V. ADJ. control, increase the voltage in 20-volt steps, noting each voltage and the corresponding count rate with a grease pencil on the overlay (don't write in the book) for the data table on page 14. To read both the voltage and the count rate on the meter, you will have to move the RANGE switch alternately between H. V. and X100, each time you increase the voltage.

10. Using the grease pencil on the overlay for page 15, outline a graph with the Y-axis representing count rate and the X-axis representing GM tube voltage. On the X-axis, divide the line into 20-volt increments, beginning with the starting potential reading. On the Y-axis, divide the line similarly, beginning with a count rate of zero. Using the data you have recorded, plot the detector plateau curve. You are interested only in finding the threshold of the plateau. Once it has been pinpointed on the curve, there is no need to go beyond those voltages and extend the curve any further. Higher voltages may damage the GM tube.

11. Add 50 volts to the voltage recorded at the threshold of the detector plateau and use this as the proper operating voltage for your GM tube in all experiments.

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